Grounding/Shielding Issues for Mechanics

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Strategy for arriving at grounding/shielding plan:

- Mechanics and services designs must advance in the near future.

- Electronics system-scale prototyping needed to test concepts will only occur after most aspects of mechanics and services are essentially frozen.

- Approach must be to define required elements of grounding/shielding scheme, leaving adequate flexibility to respond to results of system-scale prototyping when they become available.

Both DC and AC coupling between elements is important:

- Believe that most relevant frequency range is 0.1MHz to 10MHz, with the peak in sensitivity at about 3-5MHz (this describes the power supply rejection curve for single pixel front-end circuits), but we need experience with multiple modules.

Will prepare more complete document for June Pixel Week:

- For this meeting, get issues on the table for discussion...

Grounding Issues

Local Supports:

- Staves should be individually isolated from the support shell, with a provision for connection to common ground point.

- Sectors should be individually isolated from the support ring, with a provision for a connection to common ground point.

- Need to define a technique for making good quality connections from module ground to local support structure (sector or stave) after module attachment, should this prove necessary. This would most likely be a connection from the Pigtail to the local support, and should be prototyped before finalizing supports.

Arguments:

- The capacitive coupling between modules on a common local support is very high, and the conductivity of the local support is also high. The capacitive coupling between different local supports is much lower.

- Services to each half-stave or sector are bundled, and follow a common services path to USA15. Services within a bundle are strongly coupled, but have no significant pickup loops between them. Coupling between bundles will be less.

- Should we choose to exercise the connection between the module ground and the local support, we would not necessarily want to be connecting to a low-quality global mechanical ground at the same time.

Comments/Actions:

- Electrical connection techniques to carbon-carbon should be prototyped and characterized for impedance versus frequency up to 40 MHz. Possibilities include drilling a small hole and gluing a conductive pin into it, as well as simply using conductive epoxy and a wire (but surface preparation could be critical).

- Should connections from Module ground to Local Support ground be needed, the preferred approach is to connect each Pigtail to the local support directly. Less ideal schemes may need to be considered in the stave region, such as defining a commoning point at the end of the stave, and running a Module ground cable along the stave to connect all modules to the commoning point.

Global Supports:

- All elements of the global mechanical support structure (barrel shells, disk rings, and overall frame) should be electrically isolated from the local supports.

- These elements should all be tied to the common ground by a single current path, in such a way that noise currents would not flow through the global structure and shunt the Faraday cage outside. The impedance of this connection does not need to be low, but should serve to fix the structure potential close to ground.

- It should be possible to make electrical connections from the local supports to this common global support ground if this should prove useful.

Arguments:

- The global mechanical support structure is fabricated from carbon-fiber resin composites, and will not have the uniform low conductivity of the carbon-carbon local supports. It should not be relied upon in the grounding scheme.

- Every major element of the pixel detector system must be grounded to avoid having one element charge up relative to neighboring elements, possibly producing discharges, or large AC variations in potentials.

Cooling:

- All cooling connections (both inlet and outlet) should be electrically isolated close to the pixel detector. In principle, either PP0 or PP1 is an appropriate place to insert this break.

- The insulating break would ideally consist of a large insulating insertion rather than a thin insulating sleeve between conductors, in order to minimize capacitive (AC) coupling across the break.

- The cooling pipes must be grounded somewhere, independent of other details, to ensure that they do not charge up due to fluid/gas flowing through them.

- The unit of cooling is either a bi-sector (2 sectors) or a bi-stave (2 staves).

- The cooling pipes have significant capacitive coupling to the local support (due to the small distance between carbon-carbon support plates and the Aluminum cooling pipe). The pipes will be mechanically attached to the global support structure, and will be close to the power services to cool them, raising issues of both DC connections and AC capacitive coupling at the global structure level.

- The ideal solution would be to separately isolate the cooling pipe inside of each local structure from the piping at the global level. Unfortunately, it appears almost impossible to provide an insulating break at this level. This means that the cooling system will provide the most significant AC coupling between adjacent local supports, as well as a significant coupling between local supports and the global support.

- Given these restrictions, the maximum flexibility would be to DC isolate the cooling pipes from both the local supports and the global support structure. Provision must be made for possible connections to either or both local and global structures. It would be preferred to forsee possible connections between the cooling pipe and the local support at both ends of the stave.

Arguments:

- Cooling pipes are highly conductive, and must not act as additional noise current paths from the outside into the pixel detector.

- In particular, if the local supports are used as part of the module grounding scheme, it is important to minimize any additional external noise coupled from the cooling pipe into this "clean" ground.

Shielding Issues

Faraday cage:

- Create Faraday cage using Al metalization on the outside of Support Tube, Endplugs near PP1, and "inner wall" of system. The useful amount of Al required is something like 50-100μ (skin depth of Al at 1MHz is 75μ, and inversely proportional to sqrt of frequency). The double-wall beam pipe will behave as a single electrical conductor, and will have large image currents flowing on it. We should not make any electrical connection from Faraday cage to the beampipe.

- Ideally, cage should be fully closed as close to the detector as possible (PP0), but this is impossible to implement given complex service penetrations in this region. This implies closing the cage at PP1. However, a 7m long cavity has a resonant frequency close to 30MHz (albeit probably not a very large Q in our case), so we will probably need to partition the cage near PP0 to raise its resonant frequency. Can a connection be made to the metalization on the outer wall of the Support Tube near PP0 (at end of SCT barrel, where tube is segmented) ?

- Do we need to close the ends to make a Faraday cage, or are we better off with only the required inner shield (to isolate us from beam noise carried on the beampipe) and outer shunt/shield layers (to isolate us from SCT, and provide a shunt for noise currents on the service bundle shields) ? Are we better off avoiding the creation of an RF cavity inside the cage by dropping the endplugs ?

- How is the "inner wall" formed, and is it mounted directly on the beampipe ?

Cable Shielding:

- All cable service bundles (power cables associated with a given half-stave or sector) should be shielded from PP1 out, with connection of the shield at single point on the PP1 end, and individually isolated at PP2 end. Would prefer to shield individual bundles from PP0 to PP1 as well, in order to reduce coupling between different modules on different local supports, but this may not be possible inside the planned octant service trays.

Low Voltage Power Cables:

- Preferred implementation (assuming remote sensing at PP2), is broadside coupled strip lines. This is the only configuration capable of achieving low impedance and low inductance. However, if cables from individual modules are stacked, with no intervening shielding, then there is a low impedance, and a high capacitance, between the cables. Prefer to have a modest shielding layer between cables, but AC calculations needed to study its effectiveness.

- Example calculations comparing twisted pair and "power tape" configuration above show: Twisted pair will always have an impedance close to 100-120Ω, a capacitance close to 40pF/m and an inductance close to 600nH/m. An ideal power tape with 1oz Cu (35μ) and 4mm wide traces with 75μ insulator between will have an impedance of about 4Ω, a capacitance of about 1200pF/m and an inductance of about 20nH/m. Thicker conductor and larger trace separation (cable thickness) will decrease the advantage of the power tape approach.

PP2 Issues:

Three different schemes possible:

- Baseline is long (140m) cables from USA15 with current sensing supplies.

- Second option is old PP2 location with possiblity to use power tapes for Type 1 and Type 2 cables (total of about 7m from module to PP2). In this case, regulators or even DC-DC converters could possibly be used, since the gap is magnetically shielded. However, access is basically once per year.

- Third option is new PP2 location with possibility to use power tapes for Type 1 cables only (total of about 12m from module to PP2, with 9m of Type 2 cable). In this case, regulators could be used, but not DC-DC converters. Access could be weekly.

Comparison of cables for latter two schemes:

- Old PP2 and power tapes: low impedance all of the way to Type 0, about 150nH of inductance and 8500pF of capacitance for isolated supply/return line.

- New PP2 and twisted pair: impedance of about 100Ω all of the way, about 7000nH of inductance and 500pF of capacitance. This is only somewhat modified by using power tape for Type 1, since it is a small fraction of the cable run.

- Result: roughly 50 times less inductance and 50 times more capacitance for power tapes and old PP2 location. Electrically, this would be strongly preferred, but high capacitance will also exist to adjacent tapes in service bundle.

<u>Summary Comments</u>

- All modules mounted on a particular local support are strongly capacitively coupled (about 500pF between module backside and support). At frequencies most relevant for the noise analysis, this leads to impedances of 100's of ohms between modules.

- The preferred power distribution scheme from PP2 would use power tapes. In this case, there will be potentially an even larger capacitive coupling between modules within the same service bundle (half-stave or sector) due to coupling between cables.

- It may be that the best scheme to cope with these features involves implementing module grounding at the local support level, and this possibility needs to be provided for in the mechanical design of the staves and sectors. In this case, we would like to keep local structures as well-isolated from each other as possible.

Action Items:

- Further thought and prototyping should be given to key issues of connecting module ground to the local support structures, and of the optimal approach to dealing with the isolation and grounding of the cooling pipes in the local and global mechanical structures.

- Better understanding of inner shielding layer is needed. The most likely implementation, in order to cover the full length to PP1, involves wrapping the beampipe. What are the issues here ?